VALUE STREAM MAPPING TO REDUCE MANUFACTURING LEAD TIME IN A SEMI-AUTOMATED FACTORY

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***Abstract*—Growth of business world these days created tighter market competition, because the existing industrial market become more global and have penetrated the inter-states boundary. In competition which progressively tightens like this, every company claimed to own the excellence and competitiveness so that probabilities to win the competition become greater. Those conditions forced manufacturing operations to continually striving to reduce lead time of their operations. Their goal is to satisfy the customer with the exact product, quality, quantity, and price in the shortest amount of time. It can only be achieved if the company is able to create and to implement effective and efficient processes in each of its line of their business. For this purpose lean tools are used because lean focus on the continuous improvement of a company towards the ideal through the relentless reduction of waste. Value Stream Mapping (VSM) is a Special type of flow chart that uses symbols known as "the language of Lean" to depict and improve the flow of inventory and information. Value Stream Mapping Purpose is to provide optimum value to the customer through a complete value creation process with minimum lead time. For this purpose we have tried to show how the lead time can be reduced by using lean tools properly. A trim manufacturing company was being selected for case study. In this case study we have studied production process of one product and draw the current state value stream map. From the current data analysis we found out the problems and gave some recommendations to improve the production lead time and provide a future state value stream map.**

***Index Terms*—Kanban, lean manufacturing, SMED technique, value stream mapping(VSM),**

I. INTRODUCTION

The world is changing quickly, consumer expectations are high, and companies must be quick to adapt if they are to survive and thrive. Organizations need proven concepts for reducing lead time and the tools to do so if they are to remain competitive. Lean development is one such tool. Reductions in manufacturing lead time can generate numerous benefits, including lower work-in-process and finished goods inventory levels, improved quality, lower costs, and less forecasting error. More importantly, reductions in manufacturing lead time increase flexibility and reduce the time required to respond to customer orders. This can be vital to the survival and profitability of numerous firms, especially those experiencing increased market pressures for shorter delivery lead times of customized product.

For this project we worked with a trim manufacturing company. We focused on one of the company's main products, Woven tag that are used as accessory in readymade garments industries .The company is operating under the "make to order" strategy of lean manufacturing, meaning it does not keep a large inventory of finished parts and only creates a certain number of parts depending on customer demand. Our primary project goal was to reduce the current lead time by at least 50%. In order to achieve that goal, we first had to document the current state of the production process. With the creation of an initial and final state VSM, we were able to draw conclusions based on the research and data we accumulated, and we were able to achieve the primary goal of the project.

II. LITERATURE REVIEW

A. Lead Time:

Lead time can be defined as total time required to manufacture an item, including order preparation time, queue time, setup time, run time, move time, inspection time, and put away time. It is the time interval between the initiation and the completion of a production process. For make-to-order products, it is the time taken from release of an order to production and shipment. For make-to-stock products, it is the time taken from the release of an order to production and receipt into finished goods inventory. [1]

B. Lean Manufacturing:

Lean manufacturing is a manufacturing strategy that seeks to produce a high level of throughput with a minimum of input. Lean thinking changes the focus of management from optimizing separate technologies, assets, and vertical departments to optimizing the flow of products and services through entire value streams that flow horizontally across technologies, assets, and departments to customers.
The term lean manufacturing is created to represent less human effort in the company, less manufacturing space, less investment in tools, less inventory in progress, and less engineering hours to develop a new product in less time (cited from Tinoco, 2004).

C. Value Stream Mapping:

Value Stream Mapping (VSM) is a visualization tool oriented to the Toyota version of Lean manufacturing (Toyota Production System). It helps people to understand and streamline work processes and then apply certain specific tools and techniques of the Toyota Production System [2].The value stream mapping process will likely reveal that a significant amount of non-value-added activities are present in your current processes. These activities consume financial and human resources and make longer lead-time without adding value. However, some of these activities are really necessary in the process; therefore the idea is to minimize their impact [3].

Value-stream mapping can be a communication tool, a business planning tool, and a tool to manage company change process [4]. Creating a value stream map will allow the company to document current production lead time, inventory levels, and cycle times in order to determine the ratio of value-added to total lead time of the product family being analyzed, creating a vision of an ideal value flow.

The creation of a VSM is divided into five basic steps:

1. Identify the product.
2. Create a current VSM.
3. Evaluate the current map, identify problem areas.
4. Create a future state VSM.
5. Implement the final plan.

D. 5S:

The 5S philosophy focuses on effective workplace organization and standard work procedures. It is based on five Japanese words that begin with S. 5S simplifies your work environment, reduces waste and non-value activity while improving quality efficiency and safety. [5]

The 'S'	**Meaning (Japanese)**	**Objective**
1 'S'	Seiri – Sorting Out	Saving and Recovering Space
2'S'	Seiton - Systematic Arrangement	- Minimizing search time - De-cluttering the workplace
3'S'	Seiso - Clearing the work place / equipment	- Inspecting for problems - Taking corrective actions, faster
4'S'	Seiketsu - Standardization	- Achieving higher productivity and better quality
5'S'	Shitsuke – Self Discipline	- Doing it Right first

E. Single-Minute Exchange of Die (SMED):

Single-Minute Exchange of Die (SMED) is one of the many *lean production* methods for reducing waste in a manufacturing process. It provides a rapid and efficient way of converting a manufacturing process from running the current product to running the next product.

The phrase "single minute" does not mean that all changeovers and startups should take only *one* minute, but that they should take less than 10 minutes (in other words, "single-digit minute")[6]

Steps of SMED:

There are seven basic steps to reducing changeover using the SMED system: [6]

1. Observe the current methodology
2. Separate the INTERNAL and EXTERNAL activities. Internal activities are those that can only be performed when the process is stopped, while External activities can be done while the last batch is being produced, or once the next batch has started. For example, go and get the required tools for the job BEFORE the machine stops.
3. Convert (where possible) Internal activities into External ones (pre-heating of tools is a good example of this).
4. Streamline the remaining internal activities, by simplifying them. Focus on fixings - Shigeo Shingo observed that it's only the last turn of a bolt that tightens it - the rest is just movement.
5. Streamline the External activities, so that they are of a similar scale to the internal ones.
6. Document the new procedure, and actions that are yet to be completed.
7. Do it all again: For each iteration of the above process, a 45% improvement in set-up times should be expected, so it may take several iterations to cross the ten minute line.

F. Kanban: [7]

KANBAN, a technique for work and inventory release, is a major component of Just in Time and Lean Manufacturing philosophy. Kanban stands for Kan- card, Ban- signal. It is used in manufacturing to mean a visual signal that tells when it is time to get or make more of something. Within this system, workstations located along production lines only produce/deliver desired components when they receive a card and an empty container, indicating that more parts will be needed in production.

Kanban provides a simple and understandable process. It passes quick and precise information. There are low costs associated with the transfer of information. It provides quick response to changes. There is a strict limit of over-capacity in processes. It avoids overproduction. It minimizes waste. Full control can be maintained.

There are three types of kanban. They are[8]

1. Raw Material Kanban – tells suppliers when to send how much of a particular item to a particular place.
2. In-Process Kanban – determines the amount of WIP (Work In Process) that can be kept between any two operations in a process.
3. Finished Goods Kanban – determines the amount of a product to be kept on hand at any given time. Removal of material from the Finished Goods Kanban acts as a signal for more of that product to be manufactured.

G. Total Productive Maintenance:

TPM is a maintenance process developed for improving productivity by making processes more reliable and less wasteful. The objective of TPM is to maintain the plant or equipment in good condition without interfering with the daily process. It was originated in Japan in 1971 as a method for improved machine availability through better utilization of maintenance and production resources.

The Benefits of TPM are below:

- Improvements in operational efficiency
- Improvements in reliability
- Improvements in quality
- Lower operating cost
- More emphasis on planning and preventative maintenance
- Increased equipment life span
- Higher morale from improved job satisfaction and job security improvements in inventory -cost reduction

III. METHODOLOGY

The steps followed in the research are given below:

Step 1: Theoretical construction of the thesis:

Step 2: Preparation of questionnaires and database sheet based on primary observation:

Step 3: Data collection and analysis:

Step 4: Problem findings and suggest improvement scope.

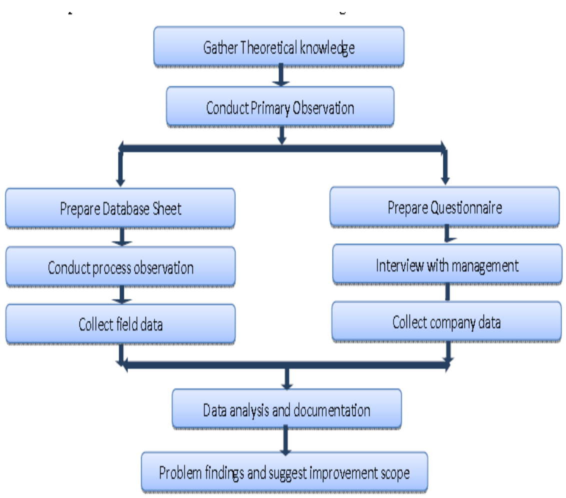

Figure 2: Flow diagram of research methodology

IV. DATA COLLECTION AND ANALYSIS

A. Production Overview of Woven Department:

Woven dept. produces labels by weaving process. Weaving is a *textile craft* in which two distinct sets of *yarns or threads* are interlaced to form a *fabric* or *cloth*. The threads which run lengthways are called the ***warp*** and the threads which run across from side to side are the ***weft*** or filling. Yarns of variable density are selected according to product requirement.

For this thesis we have decided to draw VSM which will help us to show and understand the **flow of material and information** as a product makes its way through the value stream. For this purpose we tried to follow the following steps.

- Define and pick the product family
- Collect required information
- Formulate data from field data
- Create the current state value stream map

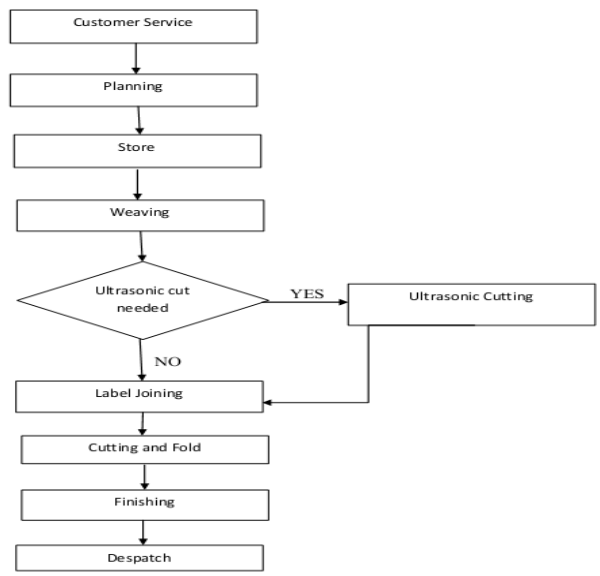

Figure 1: Flow diagram of woven department

B. Product family selection

We have seen a vast variety of labels of different types. We took an order intake file of one month and make a product family matrix. This matrix is shown in table 4.1.

Table 1: Product family matrix

Customer	Product Code	Order Qty	Store	Weaving	Ultrasonic Cutting	Label Join	Cutting	Finishing	Dispatch	Product Family
1	06/004	180574	√	√	√	√	√	√	√	1
2	06/006	33412	√	√		√	√	√	√	2
3	06/035	938778	√	√	√	√	√	√	√	1
4	06/051	2794395	√	√	√	√	√	√	√	1
5	06/052	573303	√	√	√	√	√	√	√	1
6	06/055	217458	√	√		√	√	√	√	2
7	06/056	151306	√	√		√	√	√	√	2
8	06/101	275520	√	√	√	√	√	√	√	1
9	06/105	12575	√	√	√	√	√	√	√	1
10	06/110	116168	√	√	√	√	√	√	√	1
11	06/134	42243	√	√	√	√	√	√	√	1
12	06/153	2334511	√	√	√	√	√	√	√	1
13	06/196	7594297	√	√	√	√	√	√	√	1
14	06/201	632715	√	√	√	√	√	√	√	1
15	06/366	911118	√	√		√	√	√	√	2
16	06/367	464772	√	√	√	√	√	√	√	1
17	06/380	86680	√	√	√	√	√	√	√	1
18	06/468	753517	√	√	√	√	√	√	√	1
19	06/474	310992	√	√		√	√	√	√	2
20	06/613	1155255	√	√	√	√	√	√	√	1
21	06/835	1652674	√	√	√	√	√	√	√	1
22	06/995	292000	√	√	√	√	√	√	√	1
23	06/998	260325	√	√		√	√	√	√	2

From the product family matrix we got two product families. As the product family one has to pass all the operations we can select it for our further study.

C. Effective Machine Cycle Time Calculation

The formula of effective machine cycle time is given below:
Effective machine cycle time=machine cycle time+ manual cycle time+ (change over time/ batch size)

Table 2: Effective cycle time

Process name	Manual Cycle Time	Machine cycle time	Changeover time	Batch size	Effective Cycle time
Weaving	0	272.91	1035	12000	273
Ultrasonic cut	0	84.75	1120	4500	85
Cut and fold	0	6.81	445	2400	7
Despatch	254.8	249.53	67	40	506

D. Uptime Calculation

The formula of uptime is given below:
Uptime= (Available time-Total Changeover time per day)/ Available time
The available time for the company where we conducted our research is calculated below:
One 9 Hour shift= 60 min /hr*9 hrs= 540 min/shift
Machine set up Time=15 min/shift
MDI Meeting= 10 min/shift
Lunch and Prayer Time= 30 min/shift
Tea Break= 30 min/shift
Net Operating Time= 540-15-10-30-30= 455 min/shift
Number of shift= 2.
So the available time = (455*2*60) sec = 54600sec
In the bellow table we have presented all uptime we have calculated. We used these data in our current state VSM.

Table 3: Summarized uptime for woven product processes

Process name	Available time(sec)	Average changeover/day	Changeover time	Uptime
Weaving	54600	7	2495	68.01
Ultrasonic cut	54600	6	1120	87.69
Cut and fold	54600	9	445	92.66
Despatch	54600	9	67	98.90

Table 4: Current State data summary

Process name	Store	Weaving	Ultrasonic cutting	Label Join	Cut and Fold	Finishing	Despatch
Cycle time	344 sec	273 sec	8 sec	45 sec	7 sec	201 sec	506 sec
WIP inventory		314116	627076	4284	0	133371	0
Changeover time		1035 sec	1120 sec	131 sec	445 sec	151 sec	67 sec
Available time	54600 sec	54600 sec	54600 sec	54600 sec	54600 sec	54600 sec	54600 sec
Uptime	100%	68.01%	87.69%	100%	92.66%	100%	98.90%

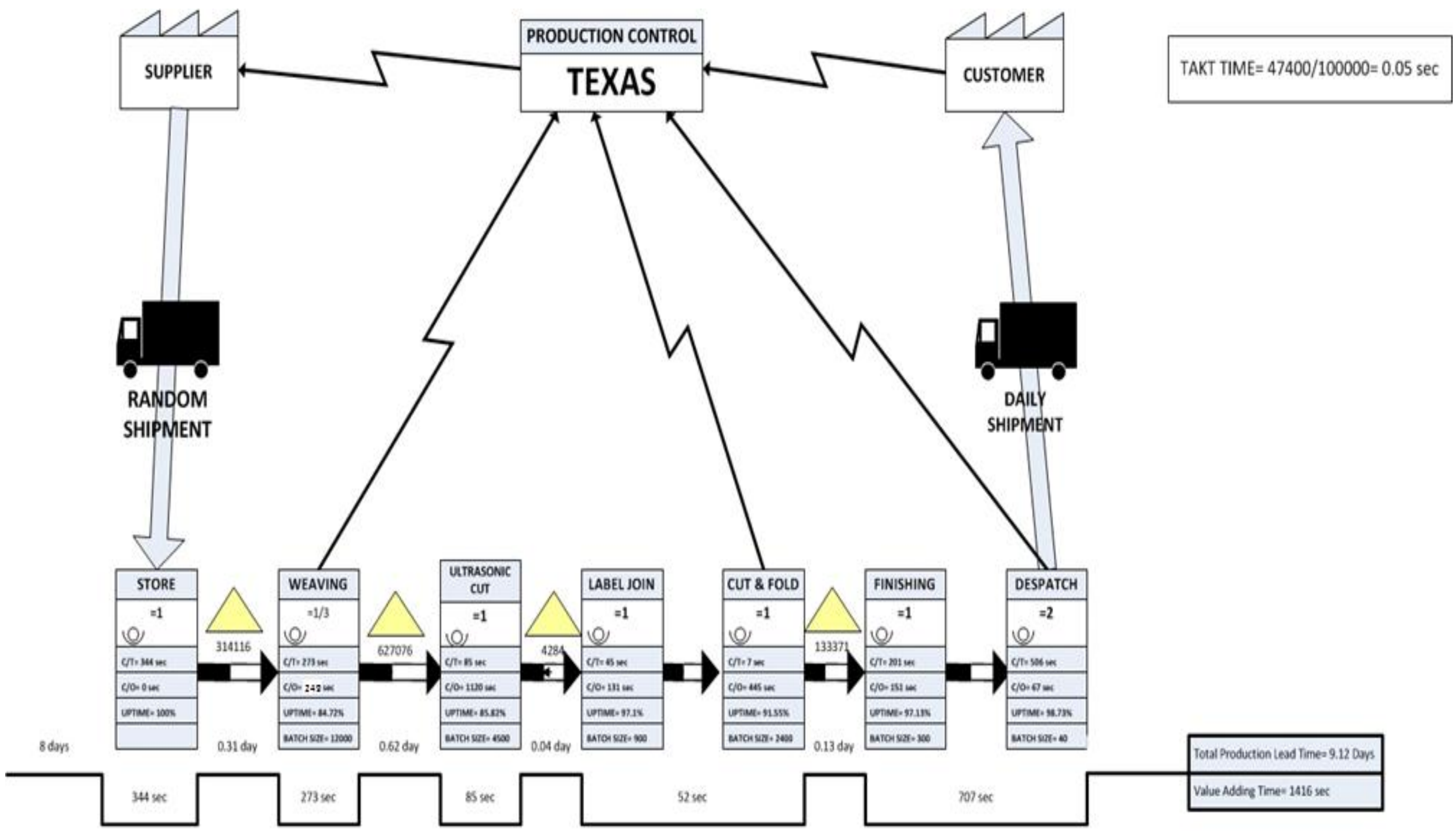

Figure 3: Current state value stream map

E. Pareto Analysis for WIP inventory

We have made the pareto chart so that we can identify the high bottle neck point.

Table 5: Pareto Analysis for WIP Inventory

operations name	WIP Inventory	Percentage	Cumulative
ultrasonic cut	627076	58.12464603	58.124646
Weaving	314116	29.11589873	87.2405448
Finishing	133371	12.36236464	99.6029094
label joining	4284	0.397090598	100
Dispatch		0	
Cutting		0	

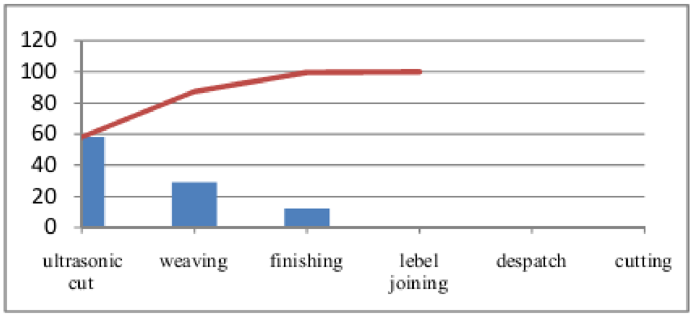

Figure 4: Pareto Analysis for WIP inventory

F. Pareto Analysis for Long Changeover Time

From the CVSM we show the change over time was high. For different operations, the change over time is given:

Table 6: Pareto Analysis for long change over time

operations name	Change over time
Weaving	2495
Ultrasonic Cutting	1120
cutting	445
finishing	151
label joining	131
Despatch	57
Store	

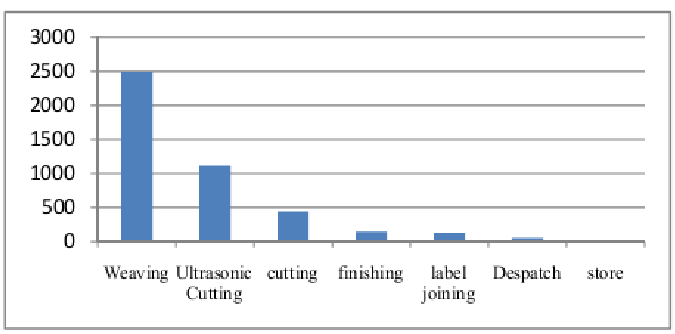

Figure 5: Pareto analysis for changeover time

V. IMPROVEMENT STRATEGIES

Work In Process Inventory Improvement Strategies

From the scoring of the cause we found four causes with high score. These are:

- Machine failure
- Insufficient capacity
- Lay out problem

A. Introducing Total Productive Maintenance

For the reduction of machine failure we have suggested to implement total productive maintenance (TPM). We have recommended following some steps to the machine operator daily. These are:

- Keeping work surfaces clean to prevent wear.
- Checking the lubrication regularly if needed lubricant the machine.
- Reporting oil leakages.
- Being alert and recognizing unusual noise, vibrations, smell and temperature which signify impending failure
- Checking bolts for tightness.
- Reporting any deterioration in product quality before the issue goes out-of-control.

B. Enhance Capacity

The machine capacity for the weaving is 0.9 million labels for 29 machines per day.

The machine capacity for the ultrasonic cutting is 0.7 million labels for 2 machines per day.

The machine capacity for the cutting is 1.4 million for 17 machines per day.

But the daily demand is 1 million labels per day.

So we have suggested increasing the machines to increase the capacity.

As the average weaving capacity of one weaving machine is 0.3 million 10 thousands, our suggestion was to increase 4 weaving machines in the department.

And the average ultrasonic cutting capacity of one machine is 0.3 million 50 thousands. So here our suggestion was to increase 1 ultrasonic cutting machine machines in the department.

C. Change Layout

Woven department has 7 sections store, weaving, label join, ultrasonic cut, cut and fold, finishing and despatch. Among them store, weaving, label join was situated in ground floor. In the 1st floor there are ultrasonic cut, cut and fold, finishing and dispatch departments. As the product first have to ultrasonic cut then label joining so the product has to transport through same way for two times. For the transportation they need 112 sec and need manpower. That's why we have given a new lay out where we replaced the ultrasonic cutting machine in 1st floor. And we have said to set supermarket in weaving and finishing section.

Long Change Over Time Improvement Strategies

From the scoring of the cause we found three causes with high score. These are

- Unorganized work place.
- Shortage of manpower
- Unconsciousness about SMED.

A. Introducing 5s

During our field data collection we saw that the workplace is not well organized. For the manual work they were not maintaining "5S" properly. So we have suggested setting their equipment in the correct place especially in label join, finishing section as they do more manual work. We have said to maintain the "5 S" properly. We have said to the management to train their operator on how to follow "5 S" and the necessity of it.

B. Increase Manpower

In this organization there is no helper for any operators. But we observed that for this reason the change over time was as high as only one person has to all the work. The transportation time was high. We have suggested hiring some helper especially for weaving and ultrasonic department.

C. Introducing SMED Technique

We've divided the whole changeover process in 2 phases.

- External activities
- Internal activities

Table 7: SMED calculation for ultrasonic cutting process

Activities	External (sec)	Internal (sec)
Check the Factory sheet,size.	120	
Level root set up by F/S		100
Set sonic cutter		388
Set sensor light		60
Run the machine slowly till product come to ruller		60
Cut the label according size	100	
Roll up the labels	185	
organized the labels according the F/S	107	
Total	512 sec	608 sec

We suggested that ultrasonic cutting machine uptime can be increased up to 54.28% by using SMED.

Table 8: SMED calculation for weaving process

Activities	Internal (sec)	External(sec)
Switch On the machine		5
check, Clean & Oiling in the all necessary point to run the Machine		600
Pick up F/S & yarn from rack.		120
Check the Factory sheet, artwork & spec .to select the machine considering warp beam.		120
Load UPT file from floppy	60	
Calculate QTY & input job		60
Attach yarn in the Accumulator based on yarn details color serial of F/S & adjust weft require tension.	135	
Run the machine until job come to the cutter line.	10	
Cutter set up as per label slitting mark. If need to sonic cut then cutter set up only	600	
Cut one piece & match quality against approved artwork & sample (such as length, width, design, lettering etc)		60
After label come out from roller then cut one pcs (for size label cut all size) &attach with QC check sheet		120
Go for QC check, if okay then run the machine for bulk. If the label quality is not okay then find out the root cause, when it is about design related issue then talk with design concern people.		600
If any label damage found about machine related issue then make a discussion with maintenance concern people to solve the problem.		5
	805 sec	1690 sec

Thus by separating the external activities we suggested to increase the machine uptime to 90.12% from 68.01%.

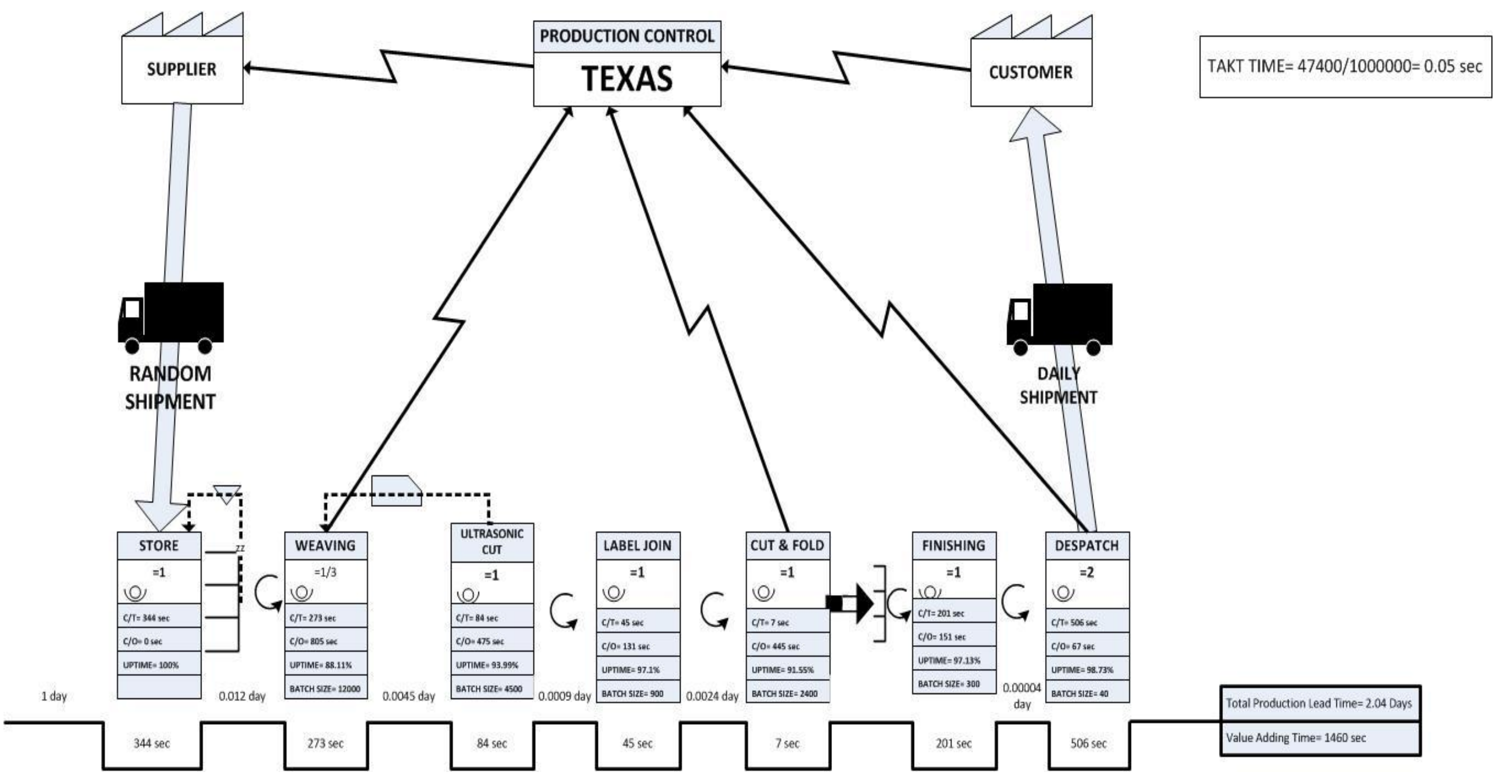

Figure 6: Future state value stream map

Table 9: Future state VSM data summary

Process name	Store	Weaving	Ultrasonic cutting	Label Join	Cut and Fold	Finishing	Despatch
Cycle time	344 sec	273 sec	84 sec	45 sec	7 sec	201 sec	506 sec
WIP inventory		12000	4500	900	2400	300	40
Changeover time		805 sec	475 sec	131 sec	445 sec	151 sec	67 sec
Available time	54600 sec	54600 sec	54600 sec	54600 sec	54600 sec	54600 sec	54600 sec
Uptime	100%	89.68%	94.78%	100%	92.66%	100%	98.90%

VI. Conclusion

Our main objective was to find the non-value added time and cut those as much as possible. For this purpose we have tried to reduce the WIP by convert the push system to pull system. We also tried to improve the process to reduce the change over time.

VII. FUTURE WORKS

Because of many limitations, it was not possible to see the total effect of the improvement strategies presented in this study. Hence the recommendations of future works on lead time reduction are given bellow:

- Our thesis was conducted in a Trim manufacturing company. But this improvement strategy can also be implied on other industries like Apparel manufacturing companies, Furniture manufacturing companies etc.

We tried to use lean tools like 5s, Kanban, SMED, VSM, TPM, root cause analysis etc. For further study we suggest to use the other lean tools and techniques like Poka-yoke technique, JIT, Heijunka, ,Jidoka, Standardized Work etc. for better improvement.

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